FURTHER DEDUCTIONS CONCERNING THE PETROLOGY OF VENUS

Louis S. Walter [1963] 4 p

A very interesting analysis of the stability of mineralogic phases on the surface of Venus has recently been presented by Mueller (1). Such a priori considerations serve to test the validity of petrologic concepts in addition to providing a framework for formulating significant investigations to be carried out by planetary probes. The purpose of this paper is to offer an extension of Mueller's ideas and to criticize several minor points in his paper. The possible existence of pools of carbonate lava on the surface of Venus will be discussed. The physio-chemical conditions assumed by Mueller will be accepted as a basis for this discussion. The surface temperature is considered to be $700°K$ and the total pressure equal to 10 atm with a relatively large amount of CO_2 and small amount of H_2O.
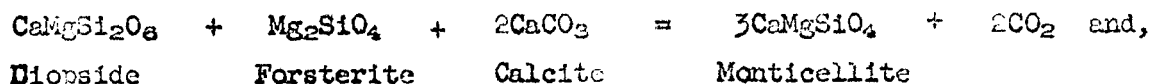
Calcium carbonate is probably unstable in the presence of silica under these conditions since Weeks' calculations (2) (which agree, at high temperatures, with the experimental determinations of Harker and Tuttle (3)) indicate that a partial pressure of 47 atm_{CO_2} is required to prevent reaction of these components. (Effects due to the activity coefficient and the total pressure on the solid phases are considered negligible due to the low pressures involved and the other severe approximations in the discussion.) Mueller's statement that the phases might coexist stably may be correct if the CO_2 pressure is greater or the temperature is less than we assume.

A rigid interpretation of Mueller's statement that the CO_2 pressure over magnesite and dolomite is much greater than that supposed for the pressure of Venus cannot be made since Weeks' data indicate that a pressure of only 0.6 atm_{CO_2} is required to maintain the stability of dolomite and 1.4 atm_{CO_2} can maintain magnesite stable. Mueller's implicit suggestion, that the pressures required to maintain the stability of

magnesium carbonates in the presence of silica is much greater than the assumed surface pressure of Venus, is, however, correct.

Although the failure of the carbonation equilibria of $MgSiO_3$ and other silicate phases such as $CaSiO_3$, $CaMgSi_2O_6$, etc. may occur at CO_2 pressures too high to be compatible with the hypothesis that any of these control the pressure at the surface of Venus whereas similar equilibria involving $CaMg(CO_3)_2$ and $MgCO_3$ may be at pressures too low, Bowen's decarbonation series (4) offers many carbonation equilibria, some of which may occur at temperatures and pressures similar to those proposed for Venus. These, then, would be the "buffer" reactions which, if CO_2 pressures tended to be low, would undergo decarbonation or, conversely, would carbonate under high CO_2 pressures. In this sense, there are mutual relationships among the temperatures as suggested by Mueller, the equilibria as suggested by Sagan (5) and the pressure. It must be remembered that the curvature of many of Weeks' P-T curves is strongest precisely in the $700°K$ region. Relatively minor variations in the surface temperature, the composition of the vapor or the composition of the solid phases may be reflected in considerable changes in the pressures of the carbonation equilibria. Thus the physiochemical parameters become increasingly significant and the experimental determination of the carbonation equilibria involved becomes more important.

Extrapolation of the high-temperature experimental data (6) to $700°K$ indicates that the reactions:

$$CaMgSi_2O_6 + Mg_2SiO_4 + 2CaCO_3 = 3CaMgSiO_4 + 2CO_2 \text{ and,}$$

Diopside   Forsterite   Calcite   Monticellite

$$CaMgSi_2O_6 + CaCO_3 = Ca_2MgSi_2O_7 + CO_2 ,$$

Diopside   Calcite   Akermanite

are, at this temperature, in equilibrium at approximately 10 atm. It may be that these reactions buffer the CO_2 pressure of the atmosphere of Venus.

The existence of carbonate melts on the surface of Venus must also be considered. Wyllie and Tuttle (7) have found that such a melt can be obtained in the system $CaCO_3$-$Ca(OH)_2$ at temperatures as low as $650°C$ at a eutectic which is at a pressure less than 27 atm. Similarly, Gittins and Tuttle (8) have discovered that the eutectic in the system Na_2CO_3-$Ca(OH)_2$ is at $595°C$ and that in the system $Ca(OH)_2$-Na_2CO_3-$CaCO_3$ at 1000 atm with 20⁺ H_2O is at $490°C$. These minimum melting temperatures will be lowered, perhaps considerable, by the addition of other components such as K_2CO_3 and even $MgCO_3$.

Recent descriptions of the active African volcano, Oldoinyo Lengai (9), state that it is ejecting carbonate lavas which are very rich in alkalies. Since the molten ejecta do not glow, a temperature less than $600°C$ is indicated. This occurrence also indicates that the pressure necessary to maintain a natural carbonate melt may be quite low.

These considerations may be quite significant in determining the nature of the surface of Venus. The amount of melting at the surface may be limited by the abundance of water in the atmosphere, but decreasing the amount of water should serve only to decrease the amount of liquid rather than to eliminate it. The degree of melting would be very sensitive to temperature.

It is not considered likely that the entire surface of Venus is covered by carbonate lava. The assumed temperature and low water content of the atmosphere would permit only the lowest-melting fraction of the rocks to form a liquid phase. It is suggested that locally, where temperatures may be higher and the abundance of alkalies greater, the surface of Venus may have pools of carbonate lava.

References

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